

**UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION III
1650 Arch Street
Philadelphia, Pennsylvania 19103-2029**

SUBJECT: Wetland Functional Analysis potentially relevant to Ex. 5 - Deliberative Process

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DATE: 14 October 14

Please find below several graphics from a bottomland hardwoods (BLH) workshop report from the mid-1980's. Up until that time the Corps of Engineers only focused on wetlands communities in the Lower Mississippi Valley such as those dominated by bald cypress (*Taxodium distichum*), water tupelo (*Nyssa aquatica*), and overcup oak (*Quercus lyrata*) in the mistaken assumption that "wetter is better".

One of the reasons for the workshop series (of three separate but cumulative workshops) sponsored by EPA was to bring the scientific community into the discussion of bottomland hardwoods ecology for a broader, more inclusive discussion of BLH issues concerning jurisdiction and ecological assessment (Roelle et al., 1987a, 1987b, 1987c).

The graphics below depict the consensus opinion of the workshop participants and generally portrays the relative degree of function across the various identified (and widely accepted) zones as described by Wharton et al. (1982). "High value wetlands" as noted in the US 460 documents seem to include all of Zone II and the lower half to two-thirds of Zone III, whereas the vaguely defined "Other" wetlands category would appear to include the balance of Zone III and most of Zone IV [with a disturbance qualifier concerning silvicultural activities which may (or may not) be addressed at a later time].

As you can see by the graphic many functions are maximized in various Zones [well supported by the literature, e.g., Conner et al., 1990; Taylor et al., 1990)] including several important functions in the upper part of Zones III in addition to all of Zone IV. For example:

- Primary Productivity
- Litterfall and decomposition
- Organic export in 5-7 year pulses (as opposed to annual)
- Consumer activity (once one combines terrestrial- and aquatic-based consumers)
- Retention of nutrients and toxics
- Biochemical transformations



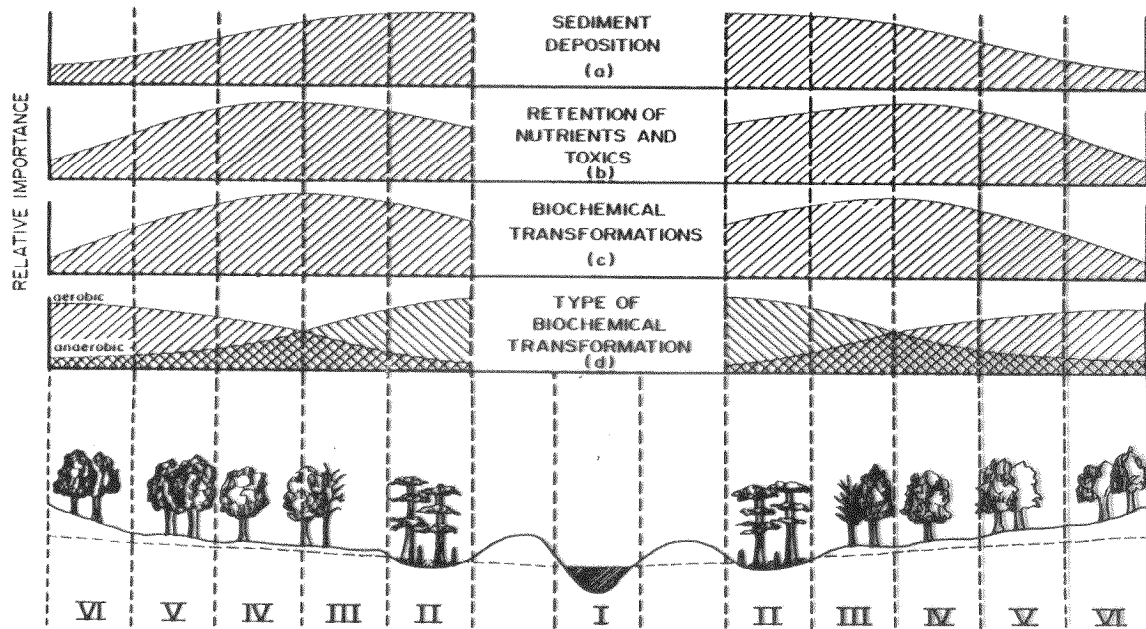


Figure 10. Patterns of physio-chemical processes in bottomland hardwood wetlands.

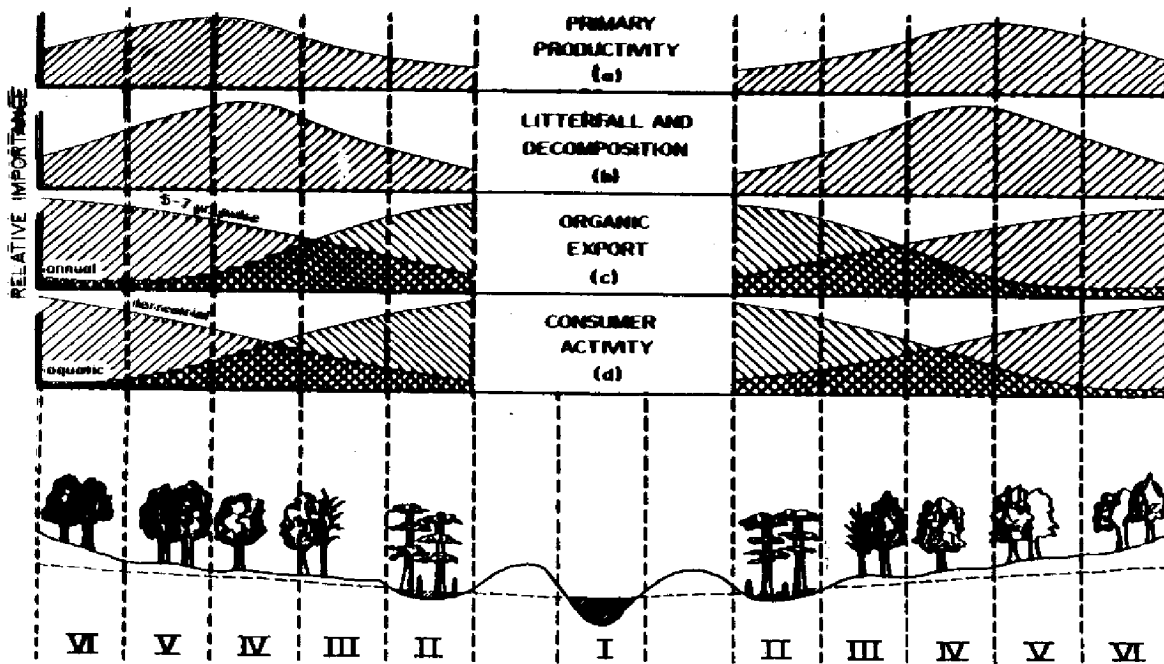


Figure 7. Patterns of community dynamics in bottomland hardwood wetlands.



In the intervening years EPA Region III (in cooperation with federal and state agencies, academia, non-governmental agencies and grant contractors) has continued to further the study of wetland classification, inventory and assessment. Efforts have culminated in regional, state and local watershed condition reports and assessments (e.g., Whigham et al., 2007, Jacobs et al., 2009).

Ecological Function in Mid-Atlantic Coastal Plain Hardwood Flats

As noted by Havens et al (2012)... “The structure and sustained functioning of mineral soil Hardwood Flats depends upon two conditions: seasonally saturated soil conditions and intact soils and vegetation communities. Hydrologic regime drives ecosystem processes in Hardwood Mineral Flats and provides the environmental conditions under which hydric soils and specialized assemblages of plants and animals have evolved.”

Based on a series of workshop recommendations and collaborations, a regional guidebook was developed to provide assessment models and methods for conducting assessments of the extent to which hardwood mineral flats of the Mid-Atlantic coastal plain perform the following four functions:

Maintain Characteristic Habitat. Conditions necessary within a site and its surrounding landscape that together provide all the resources required for maintaining the entire suite of plant and animal characteristics of unaltered Hardwood Mineral Flats.

Definition:

This function reflects the capacity of a wetland to maintain the characteristic attributes of plant and animal communities normally associated with natural Hardwood Mineral Flat ecosystems. Community attributes include presence of woody debris, tree density, component plant species such as those important as a food resource, and amount of natural area (water, forest, wetland) surrounding the site. To quantitatively determine the effects that alterations have on habitat communities in Hardwood Mineral Flats, habitat community attributes were measured at altered and unaltered sites and these attributes were statistically compared with indicator scores and other structural components used to model the function.

Rationale for selecting function:

Because animals are mobile the condition of the habitat community in a Hardwood Mineral Flat is determined by habitat conditions that occur within the site itself (onsite conditions) and by conditions offsite [i.e., beyond the wetland Assessment Area (WAA)]. Therefore, maintenance of characteristic habitat communities is modeled with a function that incorporates onsite and offsite habitat condition. Offsite habitat condition is reflected in the quality of the surrounding landscape that provides supplemental resources to animals that would normally use the site (surrounding natural lands). Plant communities characteristic of unaltered Hardwood Mineral Flats are maintained by an appropriate hydrologic regime and biogeochemical processes that require intact soil conditions. Under relatively unaltered conditions, these two parameters combine to maintain a forest of mostly hardwood trees with some pine. Tree density, the size and



number of trees, is an indicator of the degree of maturity and its condition provides information on habitat quality. Canopy tree composition represents the long-term hydrologic regime of a site as expressed by the population of mature trees. Reference standard sites tend to have higher percentages of oak (*Quercus* spp.) though most sites are dominated by the hardwoods red maple (*Acer rubrum*) and sweetgum (*Liquidambar styraciflua*) similar to sites sampled by Rheinhardt and Rheinhardt (2000) and Crazier and Ware (2001). Plant community composition and structure is modeled under the function Maintain Characteristic Plant Communities.

Characteristics and processes that influence the function:

Hydrology, plant structure, surrounding land cover, woody debris, species composition (for food).

Description of model variables: Woody debris (V_{WD}), food plants (V_{FOOD}), natural land cover within 200m ($V_{NATURAL}$), tree density ($V_{DENSITY}$).

General form of the assessment model:

V_{WD} = a measure of coarse woody debris
 V_{FOOD} = number of important plant food species
 $V_{NATURAL}$ = percent natural land cover
 $V_{DENSITY}$ = tree density

The model can be expressed in a general form:

$$FCI \text{ (i.e., Functional Capacity Index)} = (V_{WD} + V_{FOOD} + V_{NATURAL} + V_{DENSITY}) / 4$$

Maintain Characteristic Plant Community. This function reflects the capacity of a WAA to maintain the characteristic attributes of plant communities normally associated with natural Hardwood Mineral Flat ecosystems. Attributes include relative importance of component species (including percent target species, density) and the effects that alterations have on plant communities in Hardwood Mineral Flats.

Definition:

This function reflects the capacity of a WAA to maintain the characteristic attributes of plant communities normally associated with natural Hardwood Mineral Flat ecosystems. Community attributes include relative importance of component species (including percent target species, density) and the effects that alterations have on plant communities in Hardwood Mineral Flats utilizing a Floristic Quality Assessment Index (FQAI).

Rationale for selecting the function:

The condition of a plant community in a Hardwood Mineral Flat is determined by natural and anthropogenic disturbance and the soil and hydrologic conditions that occur within the site itself (onsite conditions). Plant communities characteristic of unaltered Hardwood Mineral Flats are maintained by an appropriate hydrologic regime and biogeochemical processes that require intact soil conditions.



Characteristics and processes that influence the function:

Under relatively unaltered conditions, hydrologic regime and soil condition combine to maintain a characteristic Hardwood Mineral Flat plant community. Alterations to hydrologic regime and soil conditions alter ecosystem processes in Hardwood Mineral Flats, which in turn alter their characteristic spatial and compositional attributes. Hydrologic fluctuations determine the composition of vegetation, and soil conditions control the dynamics of biogeochemical transformations by soil microbes. Hardwood Mineral Flats occur over a range of relatively narrow natural hydrologic and edaphic conditions, which in turn are responsible for vegetative community structure.

Description of model variables: Floristic Quality Assessment Index (V_{FQAI}), canopy tree composition (V_{CANOPY}), regeneration of hardwood tree species (V_{REGEN}), presence of non-native invasive plant species ($V_{\text{INVASIVES}}$).

General form of the assessment model:

V_{FQAI} = a measure of ecological conservatism

V_{CANOPY} = canopy tree composition

V_{REGEN} = evidence of regeneration of oak (*Quercus* species)

$V_{\text{INVASIVES}}$ = presence of invasive plant species

The model can be expressed in a general form:

$$\text{FCI} = (V_{\text{FQAI}} + V_{\text{CANOPY}} + V_{\text{REGEN}} + V_{\text{INVASIVES}}) / 4$$

Maintain Characteristic Water Level Regime. Described as conditions in a Hardwood Mineral Flat that affect fluctuations in water level, including variations in depth, duration, frequency, and timing of inundation.

Definition:

This function reflects the capacity of a Hardwood Mineral Flat to maintain variations in water level characteristic of the ecosystem, including variations in depth, duration, frequency, and season of flooding or ponding. The function models the effects that alterations to hydrologic regime have on fluctuations in water level. The model assumes that a Hardwood Mineral Flat will maintain its characteristic water level fluctuations if it is not hydrologically modified.

Rationale for selecting function:

Hydrologic regime is one of the main factors controlling ecosystem functions in wetlands, including those of Hardwood Mineral Flats. The timing, duration, and depth of fluctuations in water level affect biogeochemical processes and plant distribution patterns. In general, anaerobic conditions exist in hydric wetland soils, and this condition is necessary for denitrification processes to take place within these soils (Groffman et al., 2002). Much of the water quality improvement (at least with respect to nitrates) occurs in shallow groundwaters that are within the rooting zone of the wetland vegetation. Assessing the capacity of a wetland to improve water quality depends on water table elevation and the residence time of the water in this zone.



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Generally, water quality improvement will be greatest when the water resides within this zone for longer periods of time. Nitrogen enters the wetland as nitrate (from various upland, oxidized sources) and is then removed as N_2O or N_2 gas. Although some nitrogen would be lost to plant uptake and/or burial in the wetland, the atmospheric sink is considered more important to mitigating for N-rich runoff from uplands (Mayo and Bigambo 2005). Flats differ from other wetland types in that fluctuations in water level are primarily vertical, driven by a balance between precipitation and evapotranspiration (ET). Alterations to the input, export, or storage of water all change the pattern of spatial and temporal variations in hydrodynamics, which in turn affect biogeochemical and habitat functions. These alterations include impounding water, surface and subsurface drainage (ditching), fill or excavation of soil, transport of water into a site from another catchment, and changes in potential ET, microtopography, and soil porosity.

Characteristics and processes that influence the function:

Precipitation is by far the major source of water into Hardwood Mineral Flats; groundwater discharge to these systems is minimal. ET is the major export pathway, but the slow export of water down gradient (via surface and subsurface flow) is another pathway. Detailed data on hydrologic regimes in Wet Hardwood Mineral Flats are sparse, but the limited data on flats show that subsurface hydraulic conductivity is extremely low (10-12 cm/day; Riekerk 1992). Surface flow rates are generally higher than groundwater rates but are still relatively slow, primarily due to low topographic gradients of about 0.2%. In addition, hydraulic gradients of groundwater may sometimes flow counter to surface topographic gradients in the vicinity of depressions, a response to differences in transpiration rates in adjacent areas (Crownover et al. 1995). Although down gradient flows are slow, Flats tend to be extensive and therefore export large quantities of water down gradient (Wolaver and Williams 1986, Williams et al. 1992). Because Flats are low gradient, and thus not hydrodynamically energetic, most alterations to hydrologic regime (with the exception of artificial drainage) are localized in their effect on hydrologic processes. For example, a dam (even a low one such as a road fill) can impede surface flow and back water up over a large area, thus inundating the area up gradient from the dam for a longer-than-normal period. Input of excess water from offsite can likewise increase the duration and depth of water levels. On a more local scale, fill and excavation of soils alter flooding depth and duration in the footprint of the fill or excavation. These alterations to water balance change the duration and timing of flooding and the saturation of soil in the upper horizons. In contrast, artificial drainage also affects conditions offsite in that water conveyance structures (ditches and tile drains) transport water, nutrients, and dissolved organic matter to streams at a higher rate of outflow than would occur in the absence of drainage, thus altering the hydrologic regime of streams down gradient and contributing additional nutrients to them. The approach taken here was to model alterations to the hydrologic regime. The assumption is that if there has been no alteration to the hydrologic regime of a Hardwood Mineral Flat, then it will maintain its hydrologic regime, and will be within the natural range of variability characteristic for unaltered Hardwood Mineral Flats.

Description of model variables: Drain (V_{DRAIN}), Fill (V_{FILL}), Natural land cover within 200m (V_{NATURAL}).

General form of the assessment model:

V_{DRAIN} = a measure of the impact of ditching

V_{FILL} = a measure of the impact of filling



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V_{NATURAL} = percent natural land cover

The model can be expressed in a general form:

$$\text{FCI} = (V_{\text{DRAIN}} + V_{\text{FILL}} + V_{\text{NATURAL}}) / 3$$

Maintain Characteristic Carbon Cycling Processes. Conditions necessary for a Hardwood Mineral Flat to maintain carbon cycling processes at the rate, magnitude, and timing characteristic for unaltered Hardwood Mineral Flats, including indicators of organic production and alterations of hydrology.

Definition:

This function reflects the capacity of a Hardwood Mineral Flat to maintain carbon cycling processes at the rate, magnitude, and timing characteristic of the ecosystem, including export of dissolved organic constituents. This function models the effects that alterations have on biogeochemical processes and assumes that Hardwood Mineral Flats will maintain characteristic carbon cycling processes if not altered.

Rationale for selecting function:

The processes involved in biogeochemically transforming elements and compounds is fundamental to all ecosystems. However, wetlands differ from uplands in that the biogeochemical processes that require anoxic conditions (denitrification, fermentation, methanogenesis, etc.) are much more prevalent in wetlands than uplands. By supporting anaerobic biogeochemical processes, wetlands help maintain and improve water quality. The rate, magnitude, and timing of biogeochemical processes are determined by living components of an ecosystem. Primary producers (plants) assimilate nutrients and elements in soil and use energy from sunlight to fix carbon. When they die, they depend upon microbial organisms in soil to transform those fixed elements and compounds to forms that are available to other plants. Therefore, conditions that maintain plants and soil microbial populations are those that drive characteristic biogeochemical processes, such as the assimilation and cycling of nutrients from dead to living biomass and the export of dissolved organic matter.

Characteristics and processes that influence the function:

Flats differ from other wetlands due to a combination of factors that do not occur together in any other wetland type. These factors combine to control the biogeochemical processes characteristic of Flats: (a) the source of water is dominated by precipitation, thus nutrient subsidy is generally low, [Note: atmospheric deposition of pollutants is known to be problematic in the Chesapeake Bay watershed (Shedder et al., 2002; Swackhamer et al., 2004) and probably Albemarle Sound as well] (b) when flooding occurs, it may do so for long periods, but never very deeply (10-20 cm) and never with much flow velocity, and (c) microtopographic complexity is high, thus providing a diverse array of aerated and anoxic conditions for soil microbial organisms within the normal range of flooding level. Considering the characteristic biogeochemical attributes of Flats listed above, two parameters stand out as being essential for determining the degree to which biogeochemical processes are altered in a WAA: (a) the degree to which the hydrologic regime is altered and (b) the degree to which soil is altered. Because



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most biogeochemical processes in wetlands depend on the spatial and temporal balance between oxic and anoxic conditions, the timing and duration of flooding and soil saturation (hydrologic regime) affect biogeochemical processes. Therefore, alterations that affect hydrologic regime also affect biogeochemical processes.

Description of model variables:

Woody debris (V_{WD}), Floristic Quality Assessment Index (V_{FQAI}), herbaceous cover (V_{COVER}), Water Level Regime Functional Capacity Index.

General form of the assessment model:

V_{WD} = a measure of coarse woody debris

V_{FQAI} = a measure of ecological conservatism

V_{HERB} = percent herbaceous cover

Water Regime FCI score = Function capacity score from Maintain Characteristic Water Regime

The model can be expressed in a general form:

$$FCI = (V_{WD} + V_{FQAI} + V_{HERB} + \text{Water Regime FCI score}) / 4$$

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